PARAMETERS OF TWISTED PAIRS ASSESSMENT FOR FREQUENCY BAND UP TO 1 GHZ

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Abstract. *The paper describes the measuring and modeling of attenuation and near-end crosstalk for a specific metallic cable in a frequency band up to 1 GHz. The paper also includes primary transmission parameters of this cable, which consists of four twisted pairs and is designed for telecommunication infrastructures in buildings. The aim of this paper is to compare measurements and simulations obtained from appropriate models and to determine the parameters of analytic models for modelling the transmission performance of advanced transmisssion systems.*

Keywords

Analytic model, crosstalk, FEXT, NEXT, twisted pair.

1. Introduction

Today, the access telecommunication and local data networks still consist mostly of metallic cables and lines. However, generally, the symmetrical pairs of metallic cables have limited frequency band, therefore, their transmission performance will soon not be sufficient for modern multimedia services. On the other hand, replacing the present metallic infrastructures would be very expensive process that is why it still important to find some compromising solutions for increasing the transmission capacity of present metallic cables and networks. However, these potential solutions are usually based on using advanced modulation and transmission techiques, which require adequate predictions of transmission parameters of used cables and lines to be able reach high bit rate transmissions. These parameters for analytic models [6], [7], can be usually obtained by measurements.

Nevertheless, the majority of these measurements and modelings were performed only in the frequency band up to 100 MHz [4], [5]. Several models and their parameters for frequency band up to typicaly 100 MHz have been described in many papers [4], [5]. Specific measurement procedures and results of parameters were also presented there. However, the aim of this paper is to perform these measurements and modeling with appropriate calculations of necessary parameters for frequency band up to 1 GHz. Subsequently, these parameters will be used for modeling in the advanced model for Digital Subscriber Lines and data communication systems over metallic lines in local networks, based on methods presented in [6], [7].

2. Theory

2.1. Primary Parameters

The primary and secondary parameters are most frequently used to describe the homogenous lines. These parameters are influenced mainly by the structure and types of materials used for a specific metallic cable or a single telecommunication line. The primary parameters consist of resistance (1), inductance (2), capacitance (3) and conductance (4) per kilometer. The secondary parameter contains attenuation factor and phase factor and also the characteristic impedance and the velocity of propagation of electromagnetic wave throughout the line. Following formulas (1), (2), (3), and (4) describe the relation between primary and secondary parameters and were used to calculate the primary parameters for the measured cable:

$$R = \alpha \operatorname{Re} Z_C - \beta \operatorname{Im} Z_C , \tag{1}$$

$$L = \frac{\left(\beta \operatorname{Re} Z_C + \alpha \operatorname{Im} Z_C\right)}{\omega}, \tag{2}$$

$$C = \frac{\beta \operatorname{Re} Z_C - \alpha \operatorname{Im} Z_C}{\left((\operatorname{Re} Z_C)^2 + (\operatorname{Im} Z_C)^2\right) \omega}, \tag{3}$$

$$G = \frac{\alpha \operatorname{Re} Z_C + \beta \operatorname{Im} Z_C}{(\operatorname{Re} Z_C)^2 + (\operatorname{Im} Z_C)^2} . \tag{4}$$

The frequency characteristics of these primary parameters are presented in Fig. 6, Fig. 7, Fig. 8 and Fig. 9.

2.2. Crosstalk

Generally, a part of the electromagnetic wave propagating throughout multi-pair metallic cable can pass from the source pair into any of its neighbours. This negative energy transmission between pairs in multi-pair or multi-quad metallic cables is usually called the crosstalk. The near-end crosstalk (NEXT) and far-end crosstalk (FEXT) are caused by capacitive and inductive unbalances between all pairs in a cable. The additional loss of propagating electromagnetic wave and the increase of disturbance in surrounding metallic pairs are the most serious negative impacts of crosstalk in case of digital transmission systems today [2], [3]. Some manufacturing and internal constructing methods of metallic cables can be potentially used to decrease the amount of crosstalk ratio. The main difference between NEXT and FEXT crosstalk is in the point, where the crosstalk is observed. The NEXT occurs in a pair of a cable, which is measured at the same end of a cable as the transmitter, while in case of FEXT, the transmitter and receiver are located on the opposite sides of a cable.

2.3. The Methods for Measuring the Primary and Secondary Parameters

The measurements of secondary parameters of specific metallic cable were performed by a network analyzer Rohde&Schwarz FSH8 (spectral analyzer with vector signal analyzing option) with two baluns NorthHills NH16447. The local cable STP (cat. 6) length of 100 m with four twisted pairs was measured. First, the transmission parameter S_{21} of each pair was measured and after that the characteristic impedance was determined by using a method with internal impedance bridge described in [1] to obtain a S_{11} parameter. The schematic illustration of performed measurements is presented in Fig. 1.

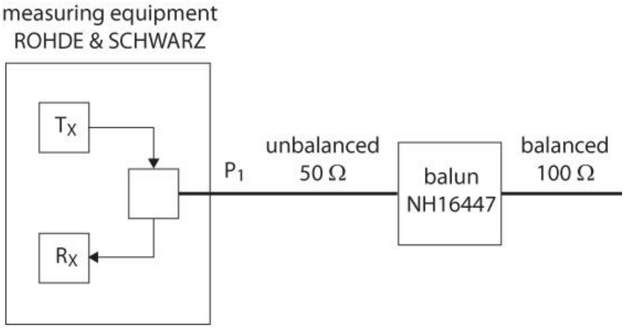

Fig. 1: Using internal impedance bridge for measuring the S_{11} parameter.

2.4. Method for Obtaining Crosstalk Characteristics

The NEXT crosstalk was measured using two baluns NorthHills NH16447 according to the schematic illustrated in Fig. 2. These baluns can be used typicaly for frequency band from 5 MHz to 1,2 GHz (limits for 3 dB decrease). It is also necessary to terminate both unused ends of pairs by proper impedances.

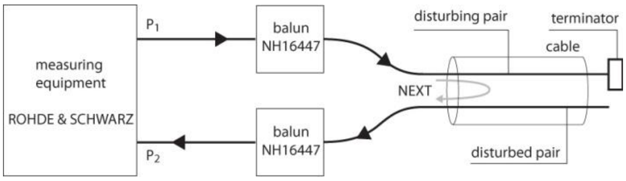

Fig. 2: The schematic illustration of NEXT measurements.

The FEXT crosstalk was measured using a similar method as illustrated in following Fig. 3.

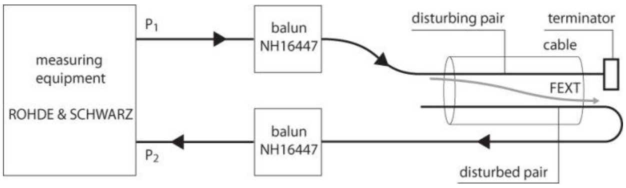

Fig. 3: Measuring the FEXT crosstalk.

2.5. Analytic Model

The frequency characteristics of each metallic cable (line) can be described by analytic models. The model of attenuation coefficient α is presented by (5), the modelling of NEXT attenuation can be performed by (6) and FEXT crosstalk can be described using (7). The process of modeling consists of obtaining necessary coefficients. In case of attenuation factor, these coefficients are k_1, k_2 a k_3 and models of FEXT and NEXT crosstalk require k_N and k_F coefficients. The coefficients can be usually obtained by using appropriate approximation:

$$\alpha = k_1\sqrt{f} + k_2 f + \frac{k_3}{\sqrt{f}}, \tag{5}$$

$$A_{NEXT} = 10\log\frac{P_1}{P_{2NEXT}} = k_N - 15\log f, \tag{6}$$

$$A_{NEXT} = 10\log\frac{P_1}{P_{2FEXT}} =,$$

$$= k_F + \alpha(f)l - 20\log f - 10\log l, \tag{7}$$

3. The Results of Performed Measurements and Models

The cable used for measurements contains four twisted pairs. The results of attenuation factor and phase factor of a pair number 1 are given in Fig. 4 and Fig. 5. The primary parameters, such as resistance, inductance, capacitance and conductance, are shown in Fig. 6, Fig. 7, Fig. 8 and Fig. 9. All characteristics were also measured and modeled for all four pairs, however, the differences between these characteristics for all pairs are not noticeable, therefore, an example for only pair no. 1 was selected. The measurements were performed in a frequency band from 1 MHz to 1 GHz.

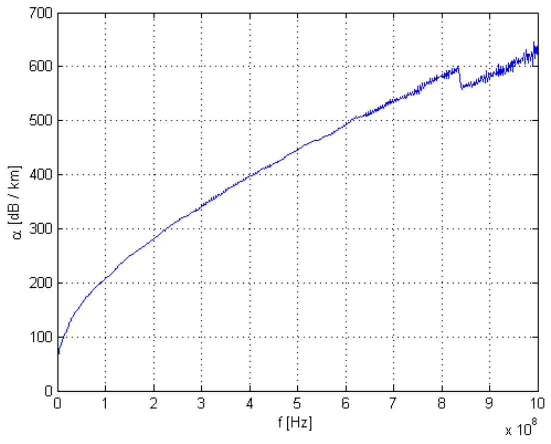

Fig. 4: Attenuation factor α of a measured cable.

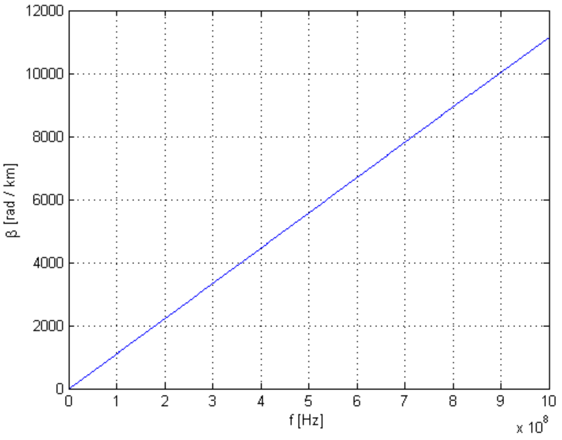

Fig. 5: Phase factor β of a measured cable.

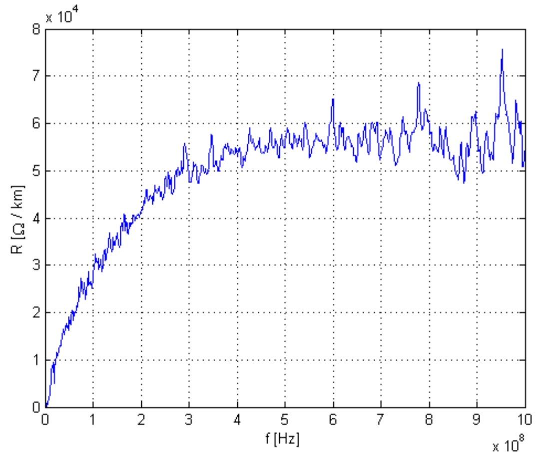

Fig. 6: Resistance per kilometer *R*.

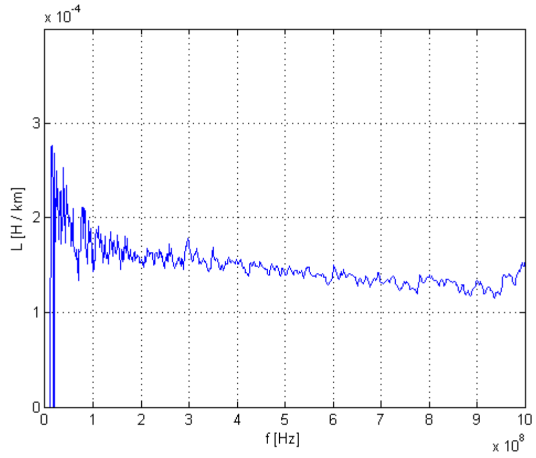

Fig. 7: Inductance per kilometer *L*.

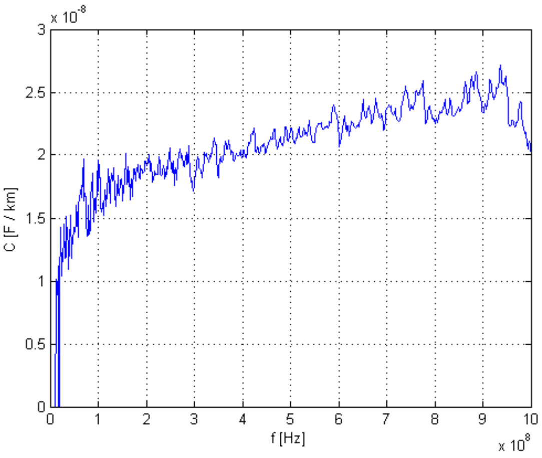

Fig. 8: Capacitance per kilometer *C*.

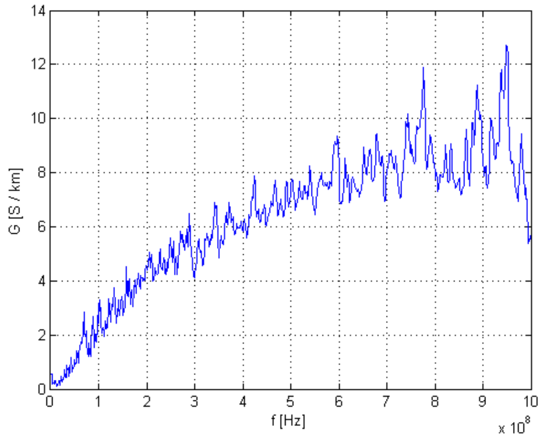

Fig. 9: Conductance per kilometer *G*.

The parameters k_1, k_2 and k_3 were calculated for a mean character of attenuation factor from all measured pairs in a cable. Thanks to that, these values can be used to model each pair of a cable. The comparison between measured (mean value) of attenuation and model according to the Eq. (5) is presented in Fig. 10. The calculation of *k* parameters was performed by using derivate-free Nelder-Mead method in Matlab environment. The values of all *k* parameters are presented in Tab. 1.

Tab.1: The values of *k* parameters.

Coefficient	Value [dB]
k_1	0,001969
k_2	5,8066e-10
k_3	6,5053e+03

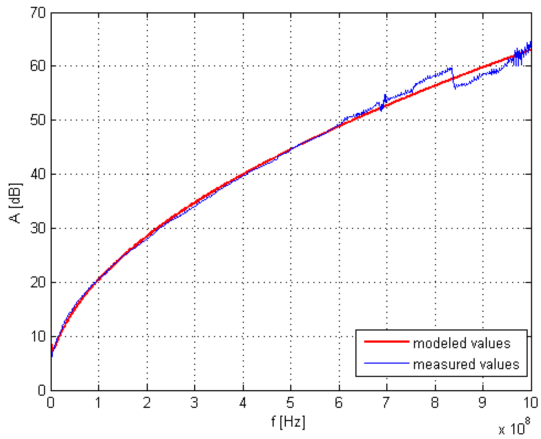

Fig. 10: Mean attenuation and model (5).

The measured characteristic of NEXT crosstalk attenuation A_{NEXT} and its model according to Eq. (6) is presented in Fig. 11.

Tab.2: The value of k_N parameter.

Coefficient	Value [dB]
k_N	213,7827

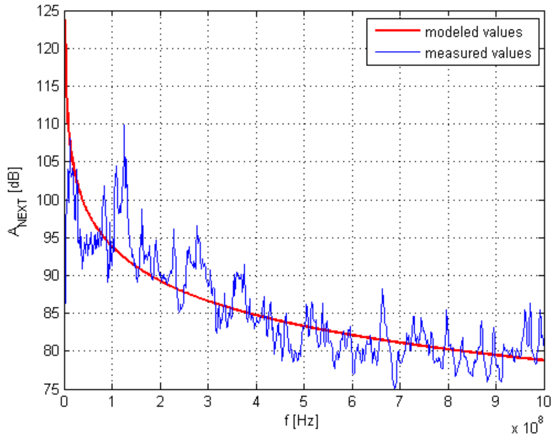

Fig. 11: The NEXT attenuation and its model.

4. Conclusion

The laboratory workplace of metallic lines and their parameters at the Dept. of Telecommunication Engineering (CTU in Prague) was upgraded and new measuring equipment was obtained. Thanks to that, this equipment was used for measuring the transmission characteristics of specific metallic cable in a frequency band up to 1 GHz. The results of attenuation and NEXT, FEXT attenuation and the parameters of their models will be further used in online xDSL simulator [8]. This simulator serves for simulations and calculations of transmission systems performance in access and local data networks. Extend the frequency range up to 1 GHz is important for future systems with speeds from 1 to 10 Gbps or more.

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Marek NEVOSAD was born in Prague, Czech Republic. He received his M.Sc. degree in electrical engineering from Czech Technical University in Prague in 2004. His research interests include telecommunication transmission systems and software development. He participates in numerous international projects focused on new methods in education as a software developer.

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